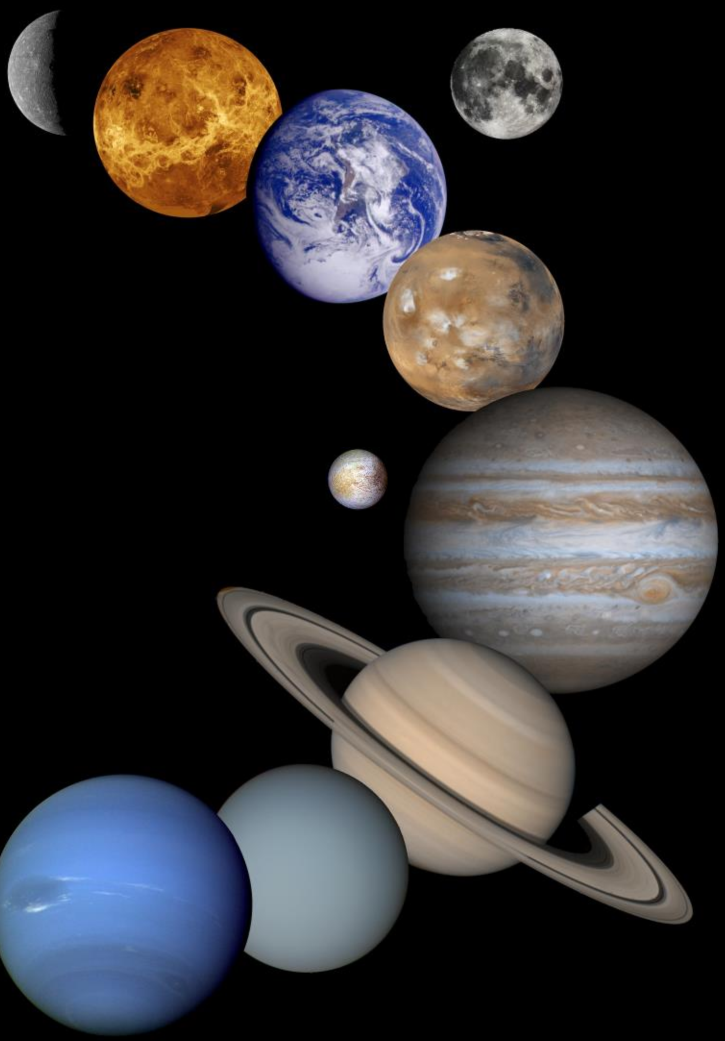
Tutorial Session 3

Planetary Protection Mission Zoo



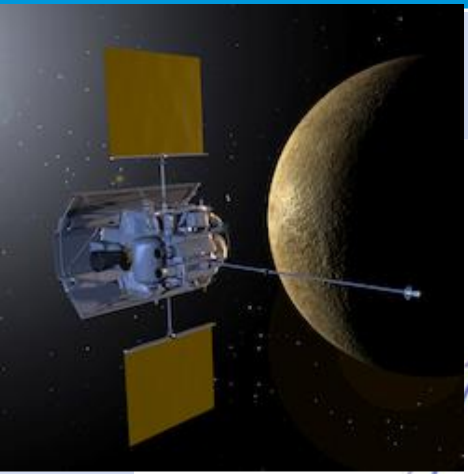
C. A. Conley

June. 2015

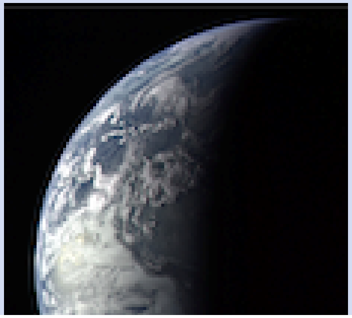
Planetary Protection Mission Categories

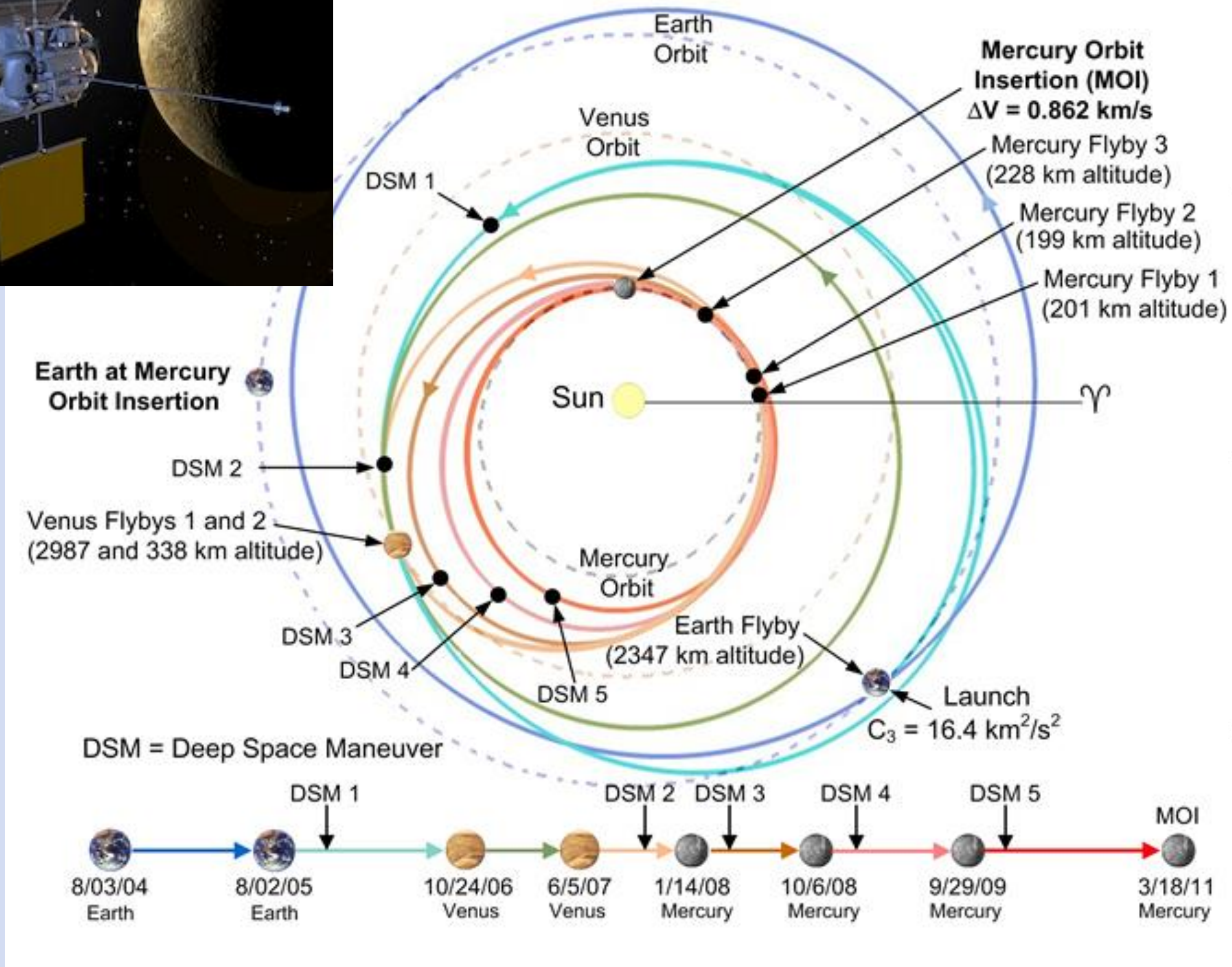
PLANET PRIORITIES		MISSION TYPE	MISSION CATEGORY
A	Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted.	Any	I
B	Of significant interest relative to the process of chemical evolution, but only a remote chance that contamination by spacecraft could jeopardize future exploration. Documentation is required.	Any	II
C	Of significant interest relative to the process of chemical evolution and/or the origin of life or for which scientific opinion provides a significant chance of contamination which could jeopardize future biological experiments. Substantial documentation and mitigation is required.	Flyby, Orbiter	III
		Lander, Probe	IV
All	Any Solar System Body	Earth-Return *"restricted" or "unrestricted"*	V

Messenger: Target is Mercury, but Category II...

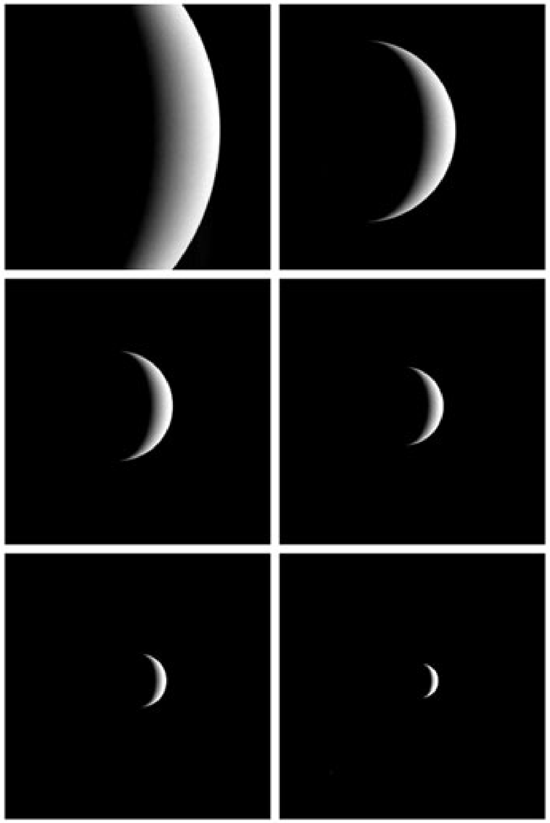


Flybys of Earth and Venus





MDIS Venus Departure Sequence (480 nm)



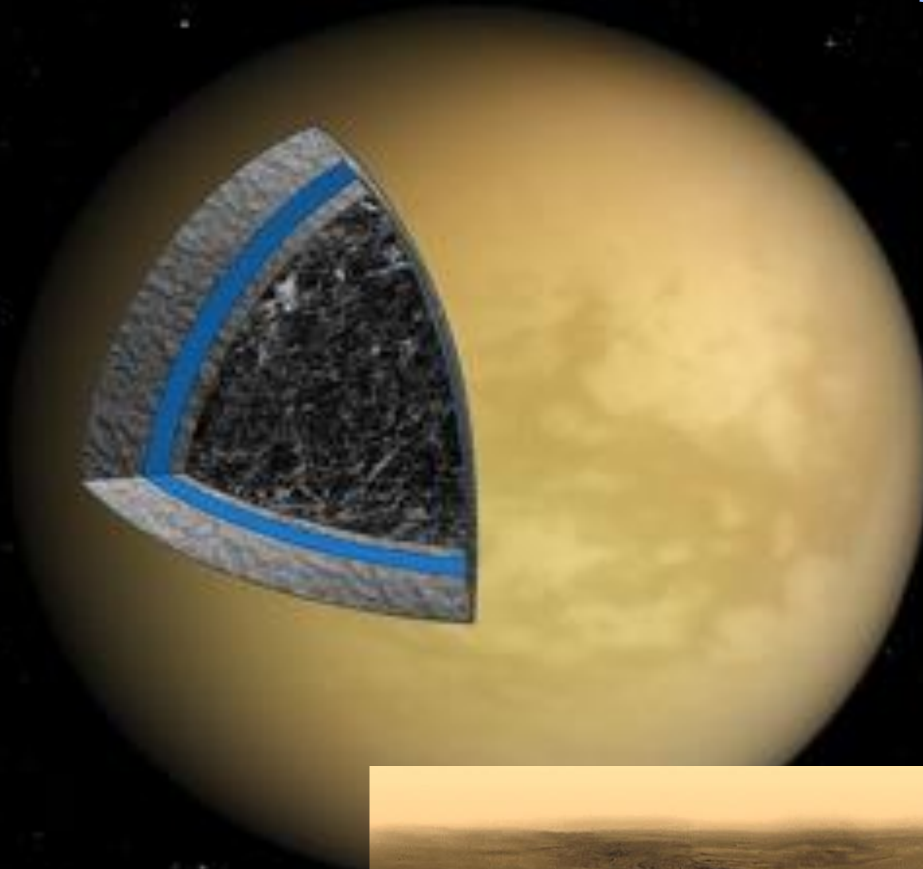
PP Category II and II* Requirements

Category II: Requirements include documentation only. In some cases an inventory of organic materials carried on the spacecraft in quantities above 1 kg may be required.

Cat. II*: For icy objects that may have internal oceans but for which the probability of contamination is 'remote,' analysis must be provided to demonstrate that the probability of introducing a single viable organism into an internal ocean is less than 1×10^{-4} per mission, focusing on the following:

- Bioburden at launch
- Cruise survival for contaminating organisms
- Probability of surviving impact/landing
- **Assessment of the presence of habitable environments**
- **Mechanisms and timescale of transport to the subsurface**

Titan—*View from Cassini-Huygens*

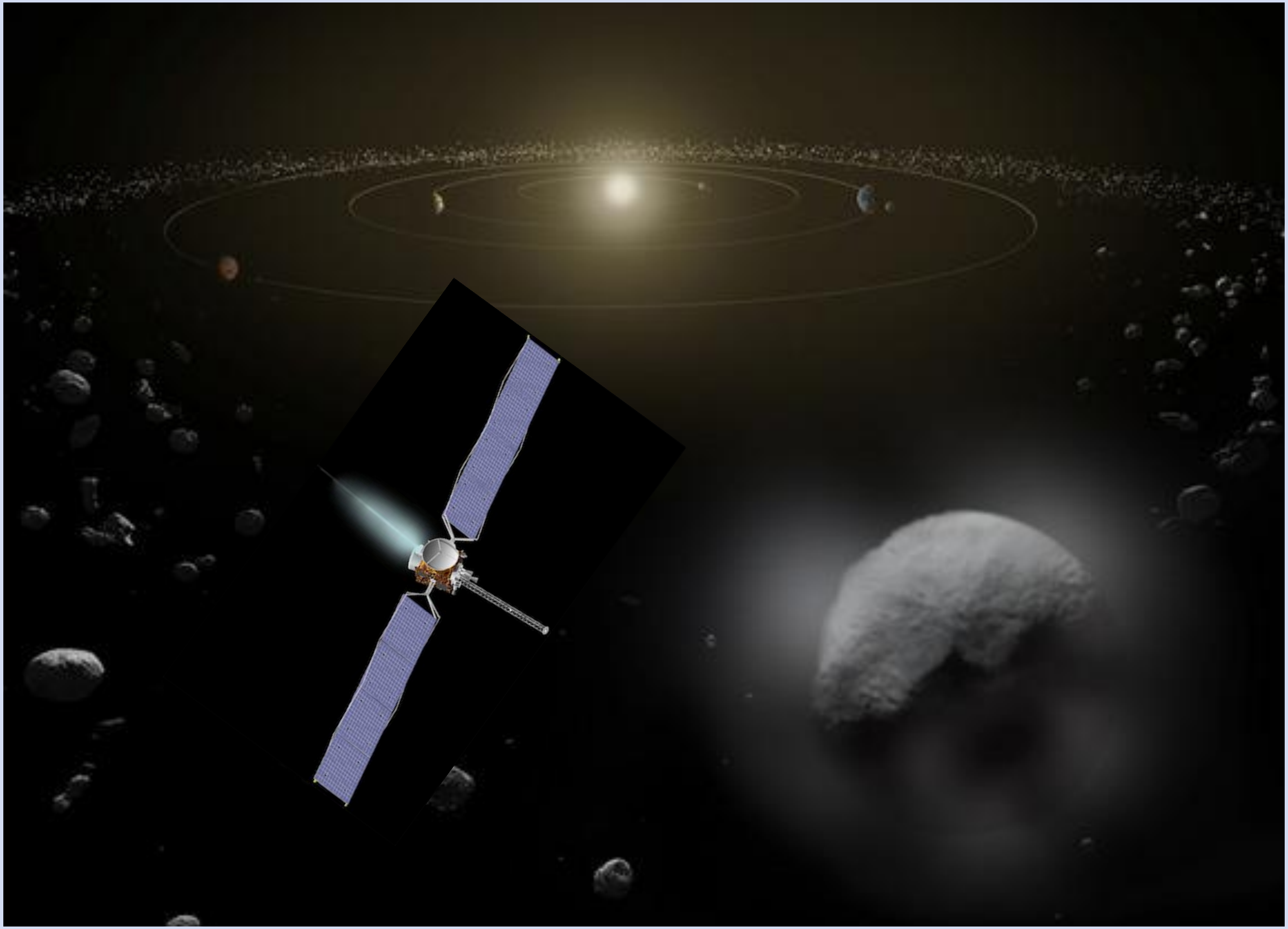


Planet Priority B Objects

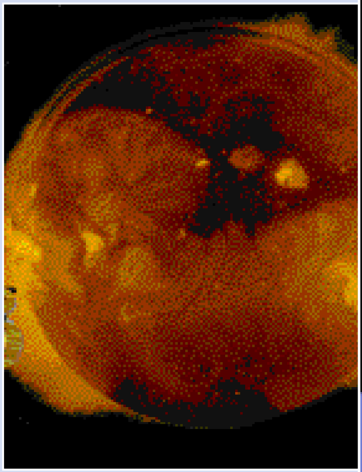
Venus; Moon (with organic inventory); Comets; most Asteroids; Jupiter; Jovian Satellites except Io, Ganymede* and Europa; Saturn; Saturnian Satellites other than Titan* and Enceladus; Uranus; Uranian Satellites; Neptune; Neptunian Satellites other than Triton*; Pluto*/Charon*; Kuiper-Belt Objects <1/2 the size of Pluto; others TBD.

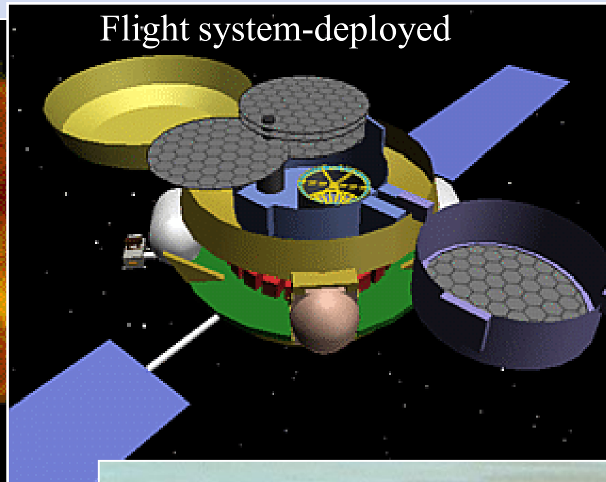
The mission-specific categorization of objects designated with an asterisk (*) shall be supported by an analysis of the "remote" potential for contamination of the liquid-water environments that may exist beneath their surfaces (a probability of $< 1 \times 10^{-4}$ of introducing a single viable terrestrial microorganism), addressing both the existence of such environments and the prospects of accessing them.

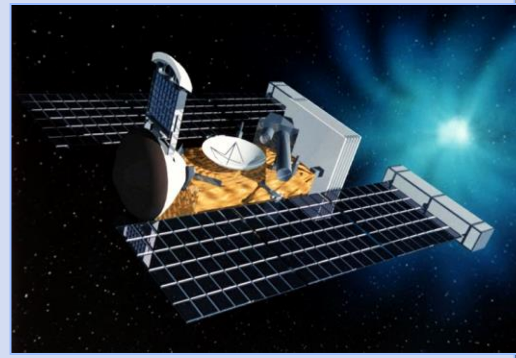
Dawn at Ceres

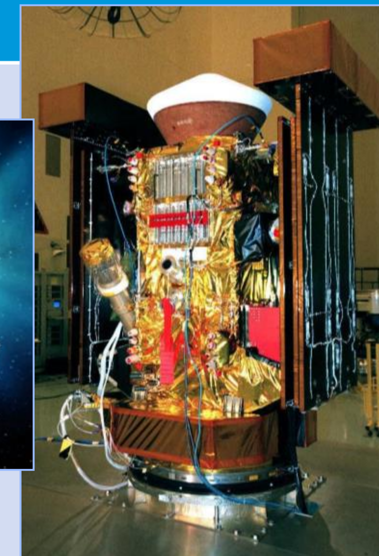


Cat.II outbound, Cat.V *Unrestricted*





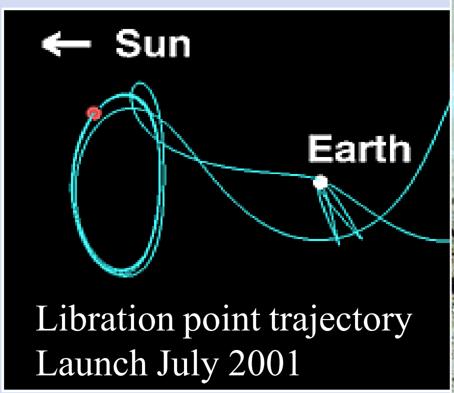




Stardust

Comet Dust Sample Return

- Returned Jan 15, 2006



Sample recovery
September 2004

Genesis

Solar Wind Sample Return

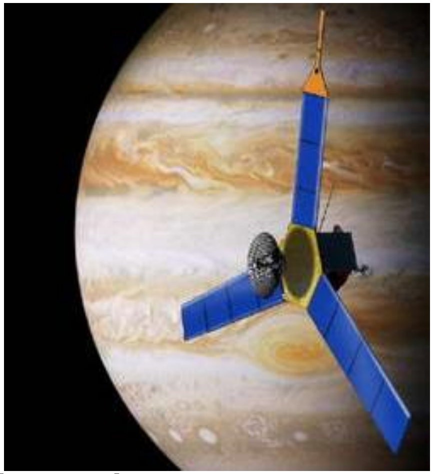
- Returned Sep 8, 2004

Category III/IV Requirements for Icy Bodies

Category III and IV. Requirements for Europa/Enceladus flybys, orbiters and landers, including bioburden reduction, shall be applied in order to reduce the probability of inadvertent contamination of a liquid water body to less than 1×10^{-4} per mission. These requirements will be refined in future years, but the calculation of this probability should include a conservative estimate of poorly known parameters, and address the following factors, at a minimum:

- Bioburden at launch
- Cruise survival for contaminating organisms
- Organism survival in the relevant radiation environment
- Probability of surviving impact/landing
- The mechanisms of transport to the subsurface

Juno Implementation Approach

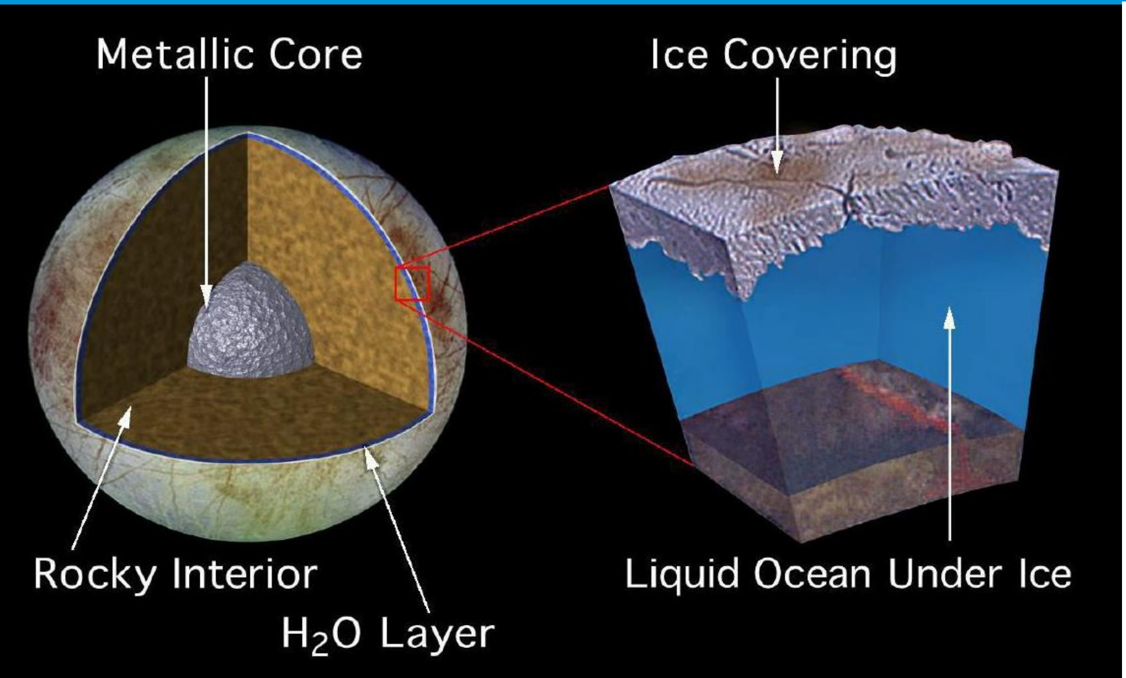


Juno proposed to meet planetary protection requirements by avoiding impact with Europa (and other Galilean satellites) via an End-of-Mission Deorbit Maneuver.

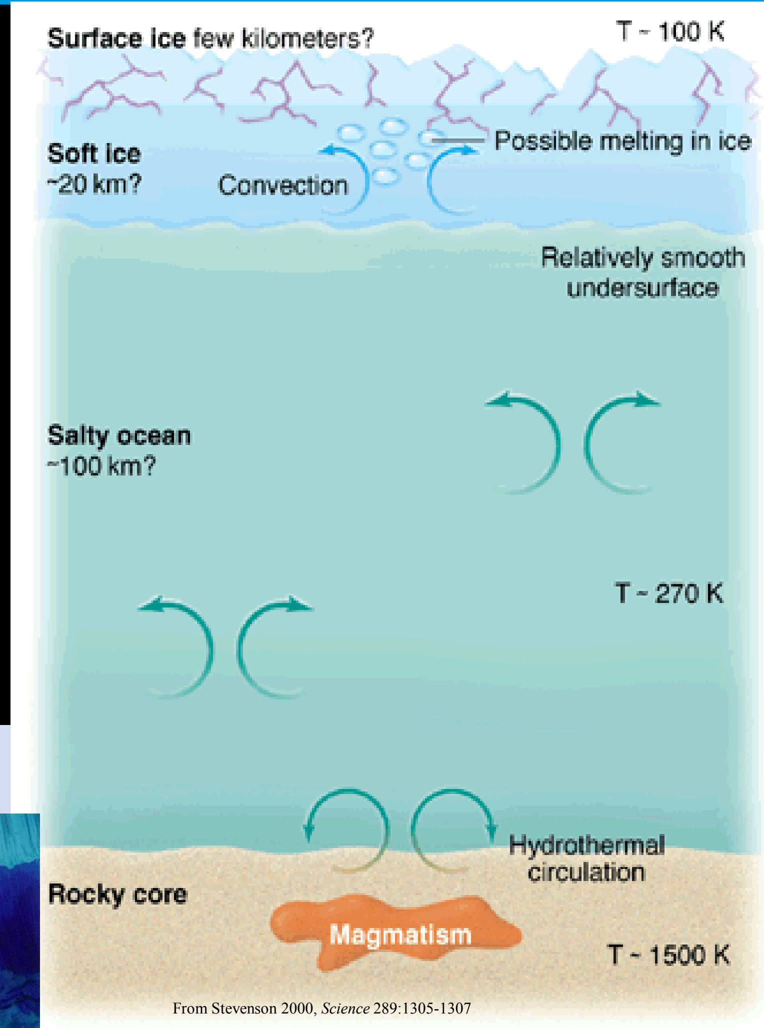
To document a 1×10^{-4} probability of introducing a viable organism onto Europa, Juno considered (among others) the following factors:

- How reliable is the spacecraft, over the entire mission phase during which Europa is in jeopardy – i.e., what happens if Juno stops working by accident?
- How long will organisms survive on the spacecraft – i.e., when does 'viable' become moot?
  - Bioburden at launch
  - Survival of contaminating organisms until impact: how lethal is the space environment?
- How likely is an Europa encounter?
- Can organisms survive the impact?
- Mechanisms of transport to the europan subsurface (COSPAR policy sets this to 1)

Europa—Focus of Future Astrobiological Study



Europa Concept...



Hydrothermal Vents?

The Mars Science Strategy: "Follow the Water"

Common Thread

WATER		
W A T E R	Geology	Understand the geological processes affecting Mars' interior, crust, and surface
	Climate	Characterize the present and past climate and climate processes
	Life	Understand the potential for life elsewhere in the Universe
When Where Form Amount	Prepare for Human Exploration	Develop the Knowledge & Technology Necessary for Eventual Human Exploration

PP Category III Requirements for Mars

Category III. Mars orbiters are required to implement one of the following two options:

- Orbital Lifetime: avoid impact with Mars for 20 years after launch at $\geq$99% probability, and from 20 to 50 years after launch at $\geq$95% probability.

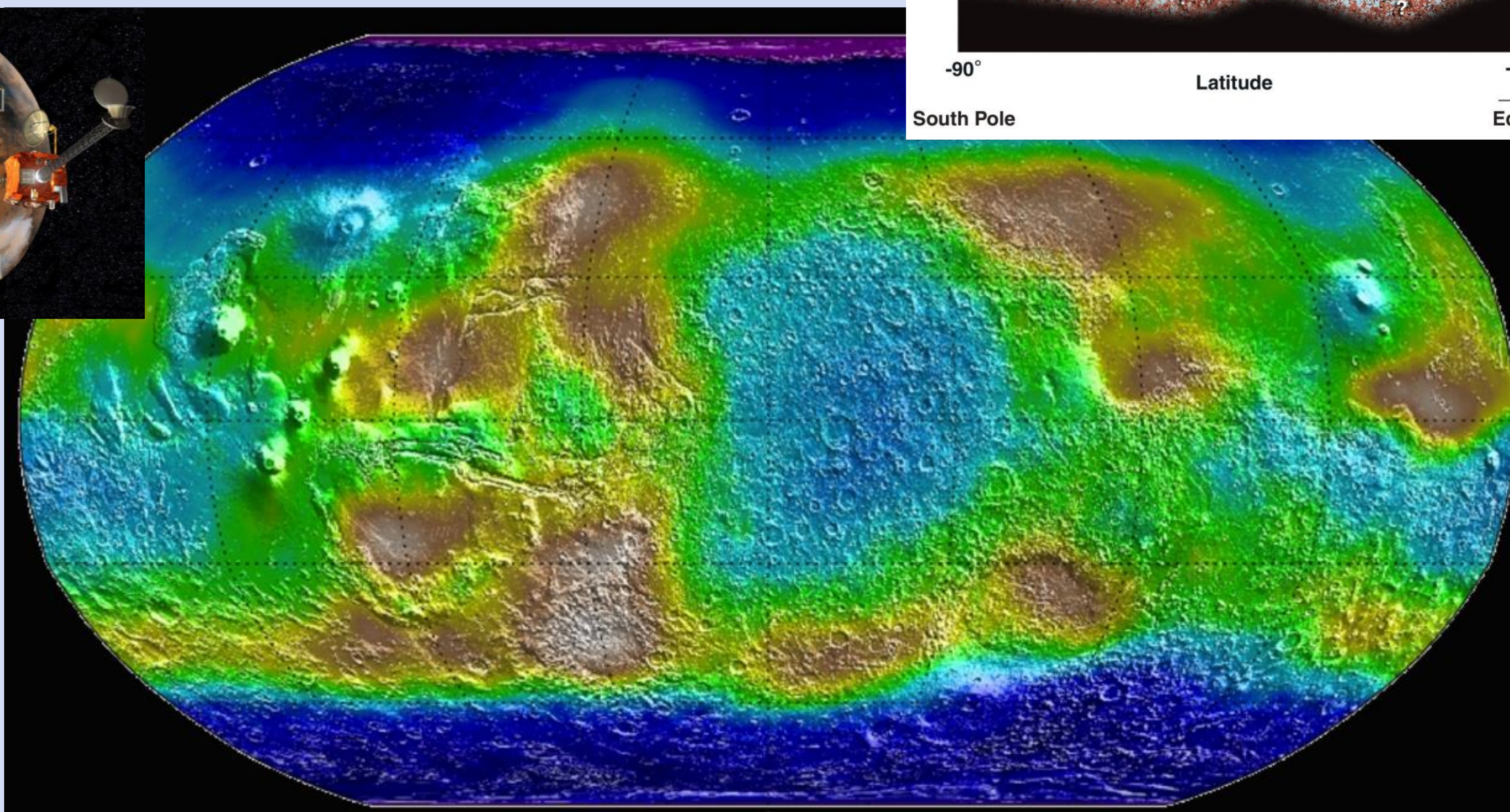
OR

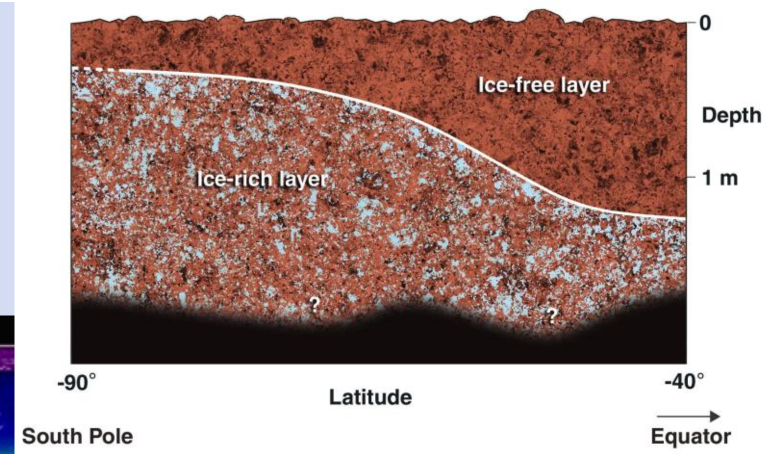
- Bioburden Control: no more than $5x10^5$ heat resistant spores in total carried on the spacecraft

NOTE: Recently, deviations have been granted to permit bioburden control compliance 'at delivery' rather than 'at launch,' given adequate supporting analyses.

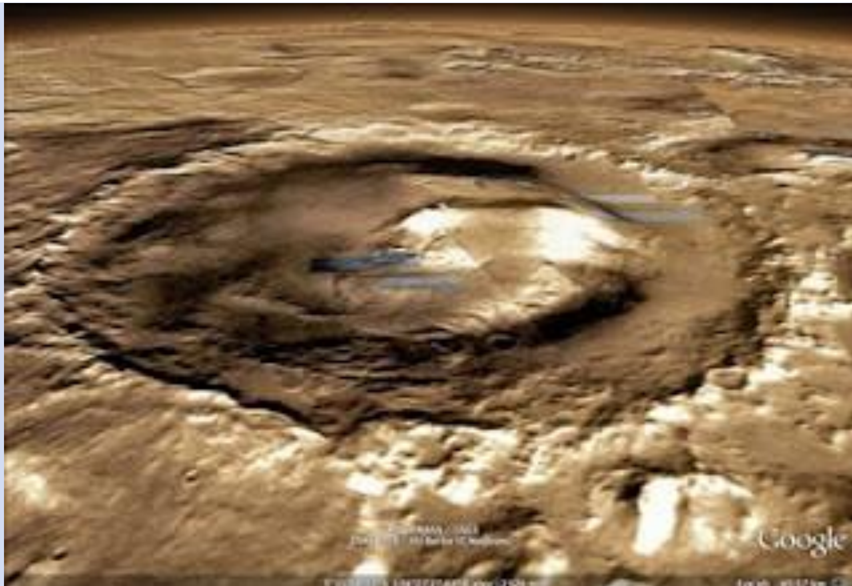
Mars Odyssey: raise orbit at EoM...

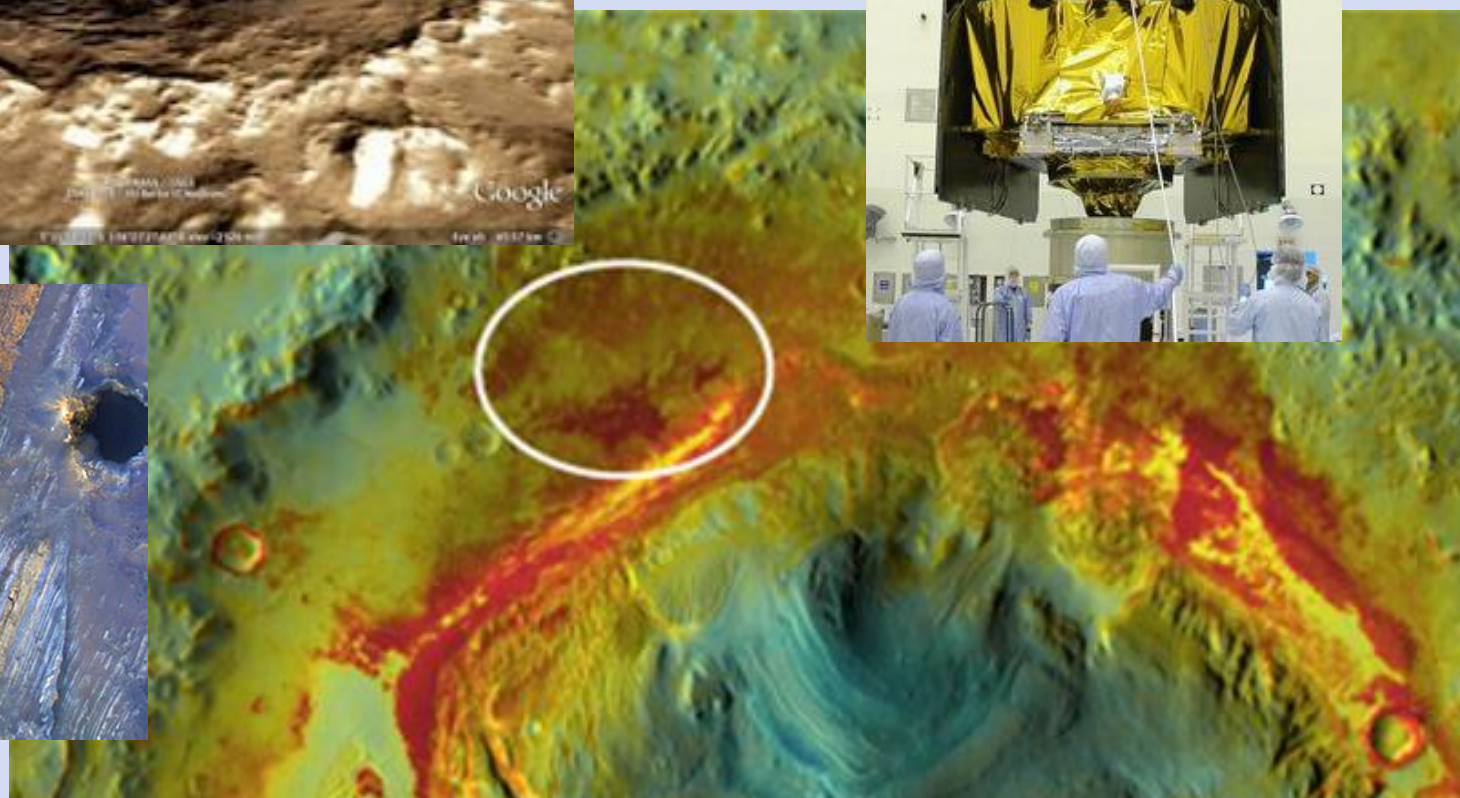
- Thermal, epithermal, and fast neutron data from the GRS and HEND instruments indicate large quantities of hydrogen—interpreted as water ice—within the top meter of the martian surface, over a *wide* area





Mars Reconnaissance Orbiter waiver from At Launch constraint...





PP Category IV Requirements for Mars

Category IV for Mars is subdivided into the three options IVa, IVb, and IVc:

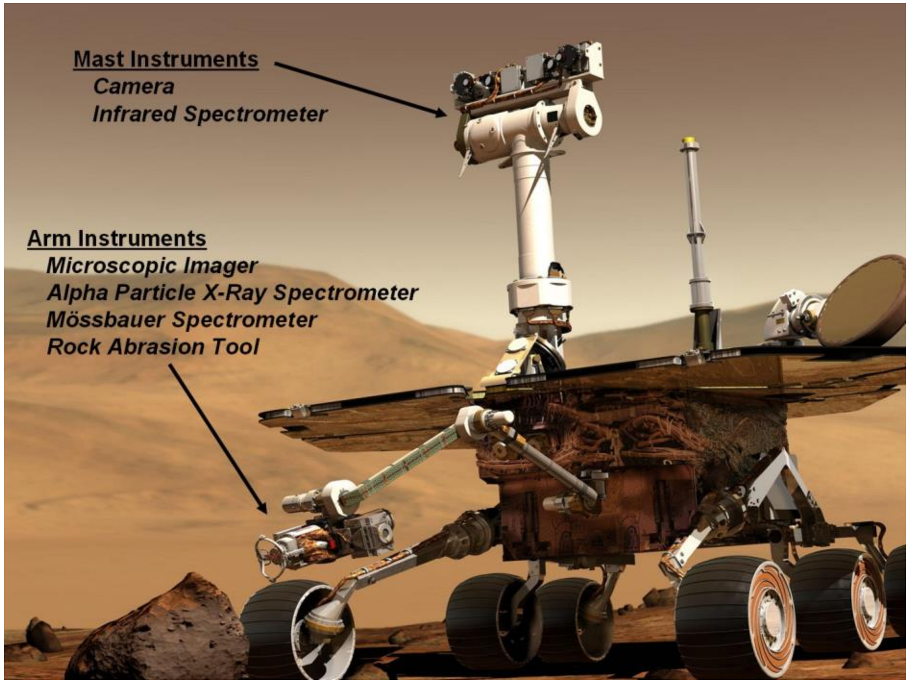
- Lander systems not carrying instruments for the investigations of extant martian life or entering special regions (Cat. IVa) are restricted to a biological burden no greater than 300 spores per square meter of surface area and $3x10^5$ on exposed surfaces.
- Lander systems searching for life (Cat. IVb) must reduce the IVa limits by 4 logs, or to a level set by the life detection instruments, at least at subsystem level.
- Lander systems entering special regions (Cat. IVc) must reduce the IVa limits by 4 logs, at subsystem level only if not landing in a special region.

Category IVa: Mars Rovers

Launched Nov. 2011; Landed Aug. 2012

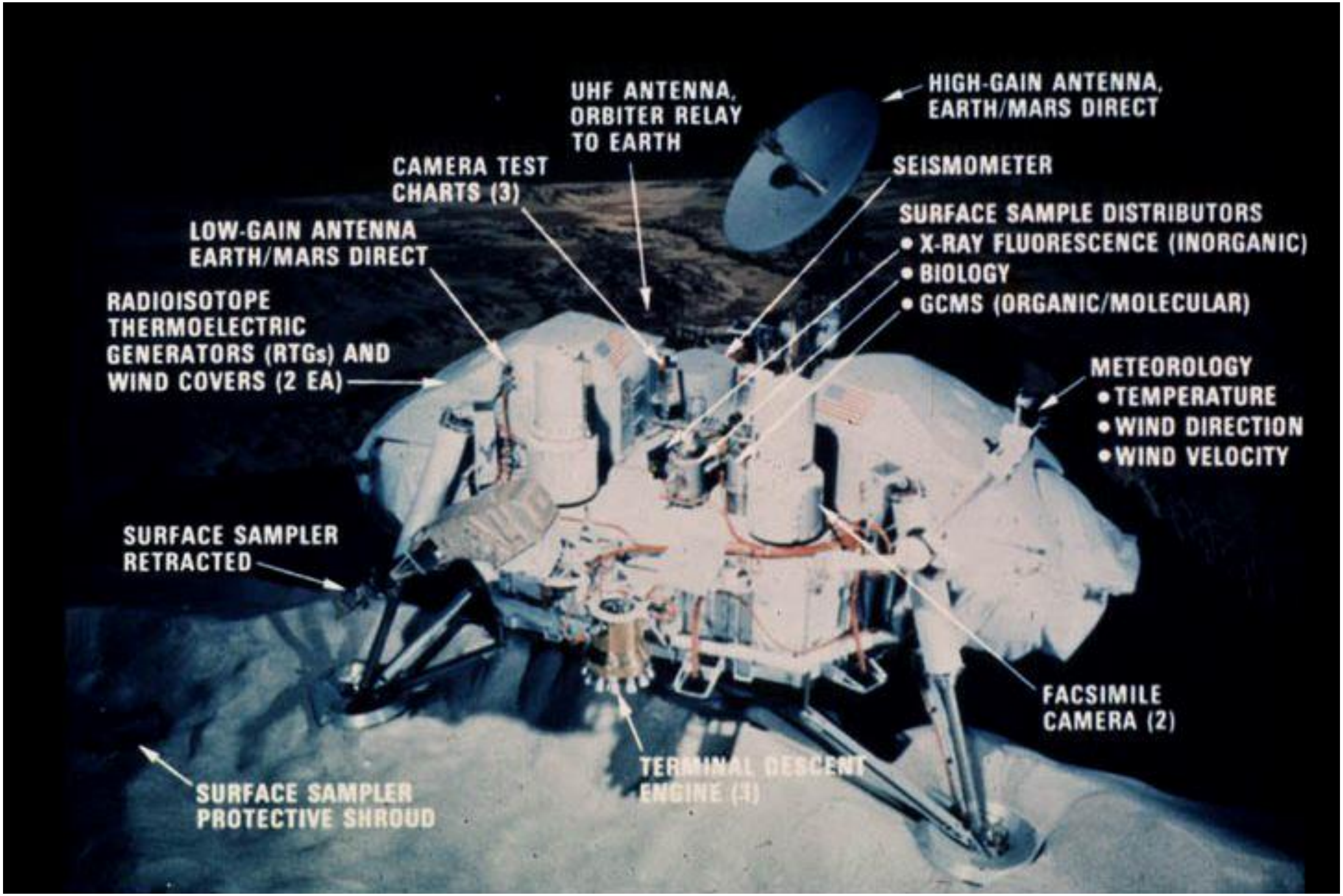
- MSL is collecting data on the climate on Mars and has found mineralogical evidence of water and elements contributing to habitable environments.

- MERs have studied the geologic record at their landing sites, and documented indications of ancient water reservoirs.

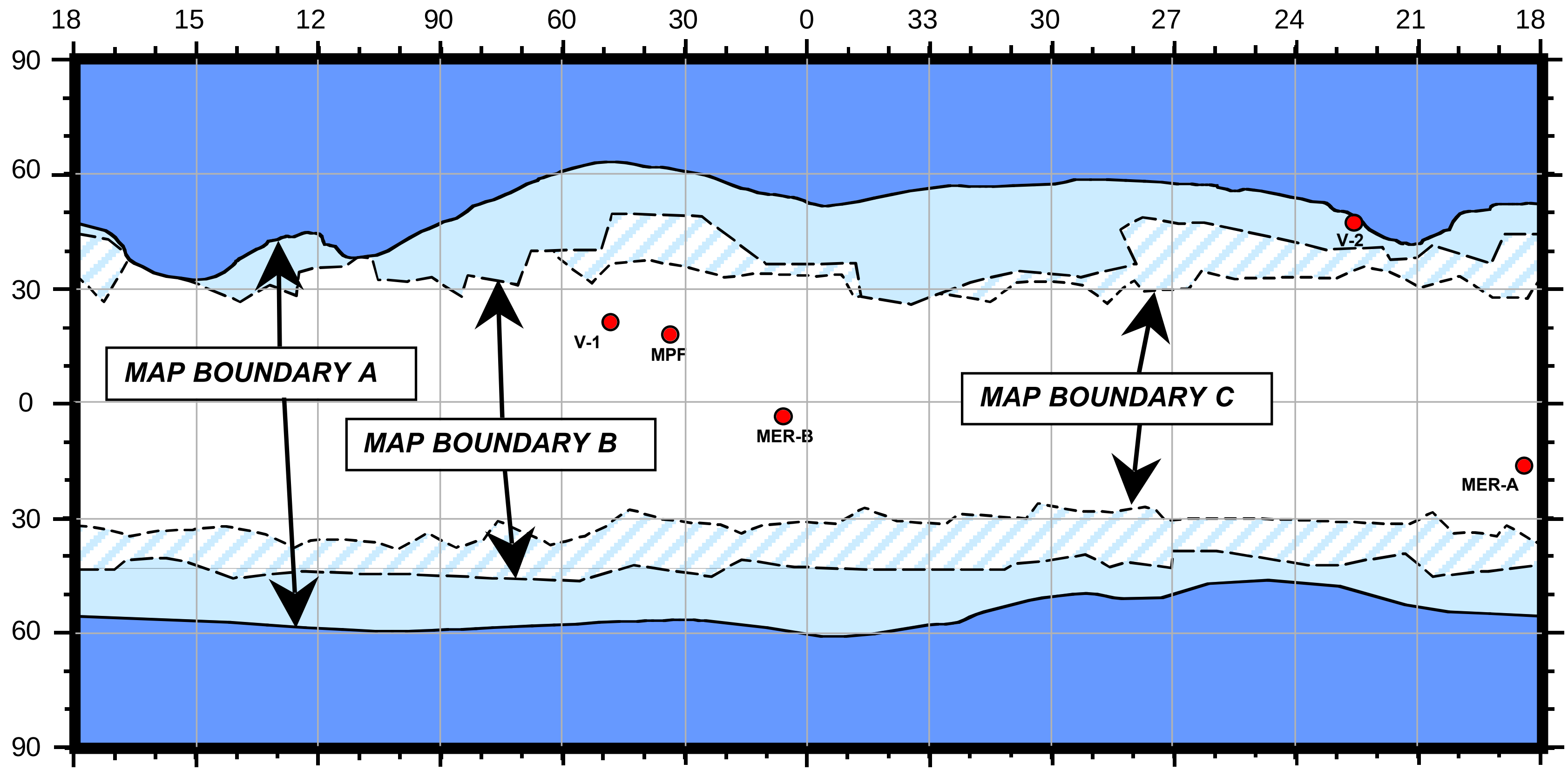


Launched: June & July, 2003
Landed: January 2004

Category IV(b, now): Viking ‘75



"Special Regions" on Mars:
Available Water, at Temperatures that Permit Growth



Map boundary A: observed equatorward limit of shallow subsurface ice (Mars Odyssey GRS)
Map boundary B: calculated equatorward limit of ice at 5 m depth
Map boundary C: observed equatorward limit of gully features

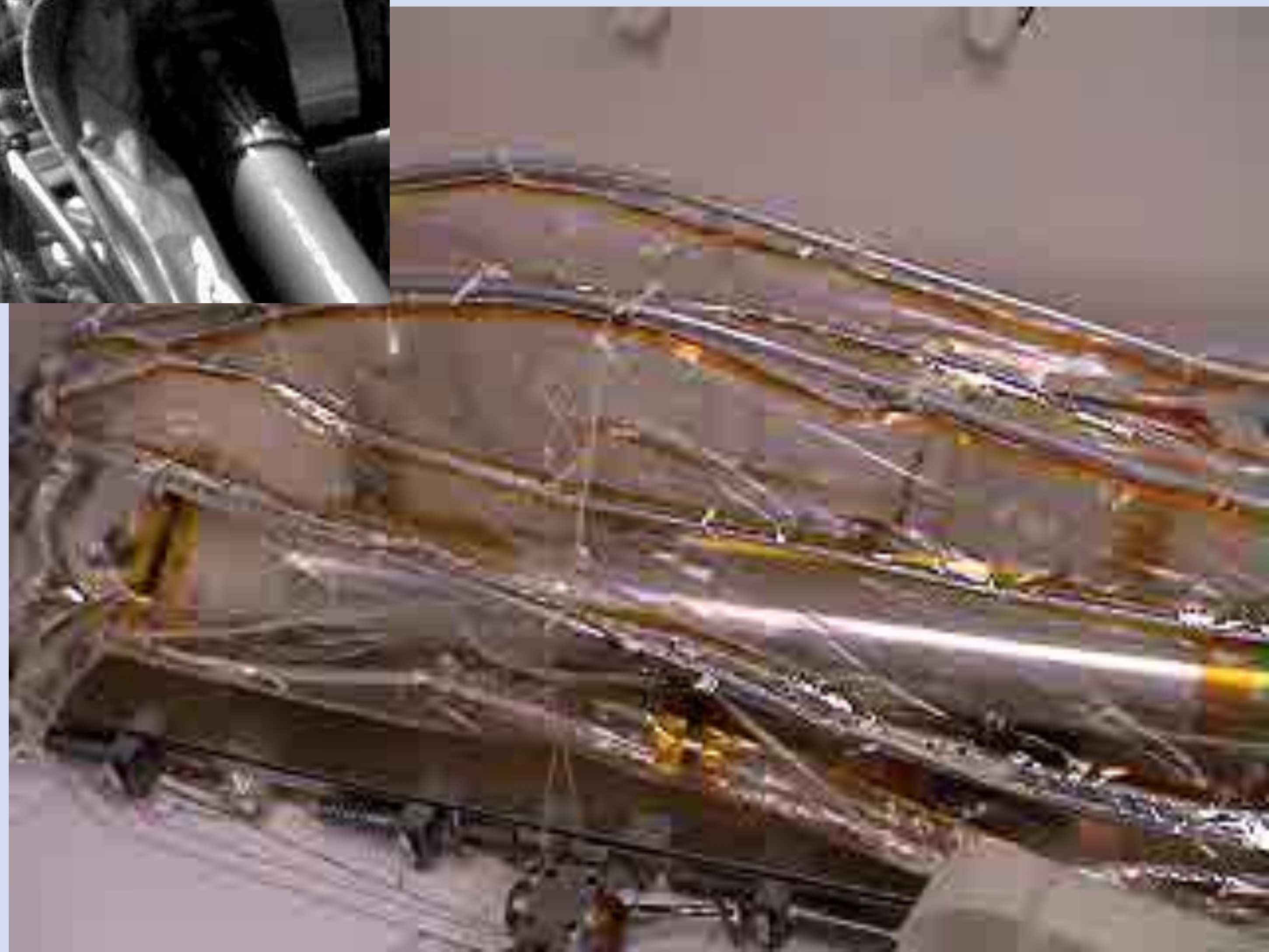
Current limits are water activity above 0.5 and temperatures above -25C:
now being revisited

Mars Phoenix: IVc

- Verification of primary and backup sites by MRO in late 2006.
- Launch August 4, 2007.
- Landing (at about 70N, 0-280E) May 25, 2008.
- Digging, sampling, and analysis phase lasts ~90 sols.
- Polar atmospheric studies continue until solar power is lost at about 150 sols.

Transiently ‘special’?

Phoenix Biobarrier Deployment Test



Category V Restricted Earth Return

- Previous requirements developed over decades of MSR preparation and adopted by COSPAR
- ESA and NASA are continuing a program of requirements refinement
- Key recommendations:

NRC: samples returned from Mars by spacecraft should be contained and treated as though potentially hazardous until proven otherwise

ESF: a Mars sample should be applied to Risk Group 4 (WHO) a priori

NRC: No uncontained martian materials ... should be returned to Earth unless sterilized

ESF: the probability of release of a potentially hazardous Mars particle shall be less than one in a million

Sample Return Campaign-Level Planetary Protection Requirements

- Campaign level categorization and individual mission-phase requirements:
  - All flight elements of a Mars Sample Return effort that contact or contain materials or hardware that have been exposed to the martian environment to be returned to Earth are designated “Planetary Protection Category V, Restricted Earth Return”
  - Landed elements must adhere to requirements equivalent to Planetary Protection Category IVb Mars missions, or Planetary Protection Category IVc should the landed element be intended to access a ‘special region’
  - Orbital elements, including hardware launched from Mars, must meet requirements equivalent to Planetary Protection Category III Mars mission

What Does 'Potentially Hazardous' Imply?

- Hazards must be either destroyed or contained
  - ➢ Contain samples or sterilize them, to ensure safety of Earth
- Must have sufficient confidence on containment
  - ➢ Requirements involve the probability of releasing a single particle of unsterilized material into the Earth environment
- Must have approved protocols for containment and testing
  - ➢ Review and update Draft Test Protocol using best available advice
  - ➢ Requirements on flight system contamination flow back from life detection protocols
- Technical requirements flow from the hazard assessment
  - – Impact on design and operation
  - – Impact on flight and ground system (C&C)
  - – Impact on hardware and software
  - – Impact on qualification and acceptance margins

Restricted Earth Return
Life Detection Considerations

- Campaign level requirements:
  - all items returned from Mars shall be treated as potentially hazardous until demonstrated otherwise: *avoid adherent dust from atmosphere*
  - release of unsterilized martian material shall be prohibited: <10nm particle at <1×10^{-6} probability: *ESF study input to COSPAR*
  - subsystems sterilized/cleaned to levels driven by the nature and sensitivity of life-detection experiments and the planetary protection test protocol: *Viking/ExoMars organic cleanliness with IVb subsystem bioburden control, and recontamination prevention through return*
  - life-detection measurements dictate limits on contamination/recontamination of the samples: *assume instrumentation at least as sensitive as today*
  - methods for preventing recontamination of the sterilized and cleaned subsystems and returned material needed: *technology development*
  - presence of a long-term heat source (RTG) would impose additional landing site restrictions to prevent both nominal and off-nominal spacecraft-induced “special regions”:

Current Capabilities Will Improve...

- Instrumentation used on returned samples will be at least as sensitive as today's instrumentation
  - Detection of organic material on surfaces can attain femtomolar/attomolar sensitivity over micron-scale spots (e.g., LDMS; other desorption techniques)
  - Detection of organic material in bulk samples can attain parts-per-billion sensitivity (ng/g)
- Capabilities to verify pre-launch organic/biological cleanliness may constrain requirements in practice
- Provisional guidance can be derived from past and current life detection missions, but additional work is necessary to assess current capabilities and extrapolate future needs

The Basic Rationale for Planetary Protection Precautions

(as written by Bart Simpson, Dec. 17, 2000, “Skinner’s Sense of Snow”)

Science class should not end in tragedy....
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